Determination of China's Foreign Exchange Intervention: Evidence from the Yuan/Dollar Market

Abstract

Purpose – The paper investigates the determinants of China's daily intervention in the foreign exchange market since the 2005 reform aimed at moving the RMB exchange rate regime towards greater flexibility.

Design/methodology/approach – The paper uses bivariate probit models to test whether China's intervention decision is driven by three sets of factors, comprising Model I (basic model), Model II and Model III.

Findings – Evidence from the models suggests that medium-term Chinese interventions tend to be leaning-against-the-wind, while long-term interventions are leaning-with-the-wind. Furthermore, by analysing exchange rate volatility this paper finds that intervention is used by the Chinese central bank to ensure that there are no big swings in the RMB exchange rate.

Originality/value – The paper will be of value to other researchers attempting to understand the policy of the central bank and, in particular, the factors that can lead to interventions during periods of financial crisis.

Keywords – Foreign exchange intervention, Exchange rate policy, China

Paper type – Research paper

1. Introduction

Intervention in the foreign exchange market is an essential tool, widely used by central banks to direct domestic currencies to a desirable level or to stabilize the currencies' movements (Sarno and Taylor, 2001). In recent years, while intervention operations have become much less common in advanced economies, research interest has shifted to interventions in the emerging markets, where this tool is now used extensively. According to a survey by Menkhoff (2013), official intervention in these economies takes various forms, and is an increasingly important force in international monetary relations.

China is prominent among the emerging economies in making considerable use of intervention. However, despite great international concern and global repercussions, there is a surprising lack of studies of China's foreign exchange intervention, including the factors that drive its intervention decision. The current research aspires to help fill this gap, and to achieve a better understanding of China's exchange rate policy.

This research contributes to the literature by establishing key properties of China's intervention, including the magnitude (in terms of time intensity), driving forces and policy behaviour. Central banks tend to operate foreign exchange intervention secretly, and this is especially so in China. In the Chinese context, the fact of intervention is obfuscated by policy jargon, in which it is described as 'exchange rate management'. In this light, our first task is to estimate when and how often China has intervened, so that one can gauge the magnitude of China's intervention measured in terms of time frequency. To do so, we search a wide range of media sources to identify the dates when China is reported to have intervened. Although media reports lack precision (Fischer, 2006), they are nevertheless valuable as a source for extracting information about China's foreign exchange intervention, given the great opacity of those operations.

We construct a sample covering 8 years, from 22 July 2005 to 22 July 2013. During the period under examination, the Chinese exchange rate regime shifted twice. On 22 July 2005, China issued an official statement announcing a shift from the dollar peg to a managed floating rate regime. However, this process was disrupted by the global financial crisis, and the RMB (Renminbi) reverted to the dollar peg around July 2008. In June 2010, as the crisis eased, the currency reverted to the managed floating system. This provides an opportunity to observe the evolving practice of Chinese interventions, including those during the global financial crisis period.

We test the determinants of Chinese intervention using 3 determinant sets: Model I (basic model), Model II and Model III. The first set comprises the medium-term and long-term exchange rate deviations from the trend, conditional volatility, and lags of intervention. The second set includes a proxy for national economic conditions and a dummy variable for exchange rate volatility. The third set includes interest rate differentials, deviations from the central parity, the foreign exchange liquidity index and foreign direct investment (FDI). In addition, in the bivariate probit estimation, we further classify the dependent variable of intervention decision into purchase and sale interventions.

We find evidence that medium-term deviations are an important factor in China's intervention that adopts a leaning-against-the-wind strategy, but long-term deviations are in line with the leaning-with-the-wind hypothesis. We perform further analysis of the influence of exchange rate movements on the days when the RMB volatility exceeds its average level, and when the yuan is appreciating or depreciating. The results show that conditional volatility can trigger intervention. In addition, in purchase intervention decisions, the Chinese central bank, the People's Bank of China (PBOC), will consider a wide range of factors, such as national economic conditions, inventory imperatives, and FDI flows. However, in decisions on sale intervention, the PBOC's main consideration is deviation from the central parity. We

find that interest rate differential is not a determinant of China's intervention, as capital controls restrict free international movement of capital, thus preventing significant effects on the RMB exchange rate.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 introduces China's exchange rate policy and estimates the timing and frequency of the country's intervention. Section 4 describes the data and variables deployed in the study. Section 5 estimates the bivariate probit models. The results are reported in Section 6. Section 7 presents the main findings of the study.

2. Related Literature

Central banks' intervention is generally motivated by the intention to move the exchange rate to a desired level and to promote market stability (Baillie and Osterberg, 1997). Almekinders and Eijffinger (1994) suggest a finer classification of intervention objectives. In the short run, central banks commonly operate to 'counter disorderly exchange market conditions' (Dudler, 1988). Then, in the medium term, they aim to combat large short-term exchange rate movements or 'erratic fluctuations'. Their long-term objectives focus on resisting deviations from fundamentals, lessening the impacts of foreign shocks on domestic monetary conditions, and avoiding undesirable impacts of currency depreciation or appreciation.

One of the chief concerns of empirical research in this field is to identify the main drivers behind government intervention. Jurgensen (1983) was among the first to study the link between long- and short-run exchange rate deviations and sterilized intervention. He found that only short-run exchange rate deviations affect sterilized intervention. Following publication of intervention data by the Japanese monetary authorities, Ito (2002) shows that deviations of the current exchange rate from its short-run (day t-1) and medium-run (previous 21 days) trend rates would prompt intervention. In addition, deviations from the policy target

of 125 yen/US dollar can also trigger intervention. In a further study, Ito and Yabu (2007) find that in addition to the influences of day t-1 deviation and the previous 21 days' deviation, the past five-year moving average of deviations is also a triggering factor. However, Herrera and Ozbay (2005) and Beine et al. (2009) do not find this factor to be significant.

Brandner and Grech (2005) study the influence of conditional volatility of exchange rates on intervention decisions for participant members of Europe's Exchange Rate Mechanism I (ERM I). The conditional volatility is gained from a GARCH model. They find that the relation between intervention and conditional volatility differs across markets. Frenkel et al. (2004) find that volatility can affect the intervention decision. However, estimating a multinomial logit model and a nested logit model, Beine et al. (2009) find that the Japanese central bank does not take volatility into consideration when making decisions on intervention. Galati et al. (2007) and Ito (2007) also obtain evidence that volatility is not a determinant of intervention.

Because of the nonlinearity in the intervention data, OLS estimates are inconsistent (Jun, 2008; Hall and Kim, 2009; Chen et al., 2012). In order to overcome this problem, researchers have applied the probit models in their intervention studies. Kim and Sheen (2002) develop a probit model to investigate the working of five determining factors behind Australian intervention: exchange rate trend deviations, conditional volatility, interest rate differentials, profitability, and inventory imperatives. Their results show that three of these five factors have significant effects on intervention; the exceptions are profitability and the inventory factor. Akinci et al. (2006) also apply the probit model to study the determinants of intervention in the Turkish economy. Similar to the Japanese results from Baillie and Osterberg (1997), they find evidence that, in the Turkish context, the main motivation of the official intervention is to reduce excessive volatility, and hence the leaning-against-the-wind hypothesis is not supported. Frenkel et al. (2004) estimate magnitude of central bank

intervention and test its determinants in an ordered probit model. Their results suggest that deviations from the target exchange rate level of 125 yen/US dollar is statistically significant for large foreign exchange intervention, but small-scale intervention is influenced by the deviation from the previous 25 days' moving average. Ito and Yabu (2007) improve the specification of this class of ordered probit model by incorporating the political cost of intervention. They find that lags of the intervention variable are significant in the model, reflecting the lower political cost of continuous intervention.

Among recent studies on intervention in emerging market economies, Loiseau-Aslanidi (2011) considers the Georgian case by using squared changes in the exchange rate as a measurement of volatility, and finds that volatility can trigger intervention. Jackman (2012) tests the Barbadian foreign exchange market and gets evidence that greater interest rate spreads may reduce sale intervention probability, but do not trigger purchase intervention. Similar research has been conducted for other emerging or developing economies, including Turkey (Akinci et al., 2006; Herrera and Ozbay, 2005), Argentina (Brause, 2008) and Pakistan (Mehdi et al., 2012). Research focusing directly on Chinese intervention has started to emerge only recently. The main contributors to this sparse literature are Chinese economists in domestic forums, with an overwhelming focus on the consequences, rather than the triggering factors, of official intervention (Lu, 1999; He, 2007; Xie et al., 2008; Liang and Mo, 2013; Wang, 2013).

3. Official Intervention in China and its Measurement

3.1 Evolving RMB Exchange Rate Regime

The reform to China's currency regime in July 2005 ended a decade-long fixed exchange rate system. In a policy statement at that time, the Chinese central bank announced that the RMB would be managed 'with reference to a basket of currencies' instead of being pegged to the

US dollar. As a result, greater flexibility was phased into the new regime, and the exchange value of the RMB came under the influence of market supply and demand. The renminbi exchange rate could now fluctuate within a narrow margin around a base rate known as the central parity rate.

Under this managed floating rate regime, the RMB exchange rate was no longer determined solely by the US dollar, but also by the movements of a basket of international currencies. According to Zhou Xiaochuan (2005), Governor of the PBOC, the reference basket contained 11 currencies, with the US dollar, the euro, Japanese yen and Korean won as the first-tier heavy weights, while the second-tier currencies comprised the pound sterling, the Singapore dollar, Russian rouble, Malaysian ringgit, Australian dollar, Canadian dollar, and Thai baht. The weight of each currency was determined according to its importance in China's external trade.

However, when the global financial crisis hit, the dollar peg was unofficially reinstated. This unofficial re-pegging started in mid-2008 and lasted until June 19, 2010, when the Chinese central bank announced that it would 'proceed further with reform of the RMB exchange rate regime and increase the RMB exchange rate flexibility'. Since then, the Chinese exchange rate regime has reverted to the managed floating rate system based on market supply and demand with reference to a basket of foreign currencies.

Initially, the daily trading price of the RMB against the US dollar was allowed to fluctuate only within a narrow 0.3% band around the central parity. On 18 May 18 2007 this band was expanded to 0.5%, and then on 16 April 2012 it was expanded yet further, to 1%. On 15 March 2014, the State Administration of Foreign Exchange (SAFE) announced that, in the inter-bank foreign exchange market, the bid-ask spread of the daily trading price of the US dollar against the RMB would fluctuate by a maximum of 2% each way around the

central parity rate. Thus, over time, the RMB has gradually been allowed more room for fluctuation.

3.2 Forms of Chinese Intervention

The Chinese government has been reluctant to admit that intervention has ever occurred in China's foreign exchange market, fearing that such an admission would fuel international pressures for the RMB to appreciate. However, from observation of China's policy practice, it is possible to detect three major operations that the Chinese monetary authorities use to influence the foreign exchange market:

(1) The central bank intervenes by directly purchasing or selling foreign currencies in the marketplace. In the case of purchase intervention, the central bank buys foreign currencies with central bank notes; in sale intervention, it sells foreign money to withdraw the renminbi from the market. We term this type of intervention 'CB intervention', as it involves the central bank participating in market transactions.

(2) The central bank controls the level and growth of the RMB exchange rate by specifying on each day a central parity rate within a permissible range in which the daily trading prices of the RMB are allowed to fluctuate in the marketplace. We call this 'CP intervention', since this intervention operation involves the setting and adjustment of the central parity.

(3) Intervention may also take an oral form, including, for example, policy briefing, moral persuasion, formal and informal meetings, and telephone conversations. We call intervention through such channels oral intervention. Here, the Chinese central bank effectuates intervention by instructing or directing the attention of market participants towards 'things to note'; it does so particularly with traders of state-owned banks, who are a dominant force in the Chinese foreign exchange market.

3.3 Measuring Intervention

Of the three major forms of Chinese official intervention, the current study focuses on CB intervention, in which the central bank intervenes by directly purchasing or selling foreign currencies in the marketplace. To analyse the CB intervention, we first try to detect the time and time intensity of the Chinese operation. Following Beine et al. (2009), we search the global news reports that indicate possible PBOC intervention as evidenced in the statements of market traders and analysts. We scrutinize the newswire reports in Factiva and Reuters China that mention the PBOC, adopting two basic rules: First, when it is reported that direct central bank intervention has occurred, we mark this day as a CB intervention day. If the Chinese monetary authorities are reported to have purchased (sold) foreign currency (e.g. the USD), that day is designated as 1 (-1), and 0 otherwise. Second, when there is reporting of CB intervention via the state banks (indirect purchase or sale of foreign exchange), we also mark this as a CB intervention day and the sign of such intervention is marked the same as above (plus for purchase and minus for sale intervention). In determining the dates of Chinese intervention we take account of CB intervention information at various degrees of certainty, such as likely, clearly, covert, suspected, think, may have, and rumour.

For the purpose of illustration, on 10/11/2012, news reports indicate that, believing the RMB exchange rate to have appreciated sufficiently, state banks including the Industrial and Commercial Bank of China and the Agricultural Bank of China started to buy the USD, which pushed up the dollar price. Four traders in the market viewed this as reflecting official intervention. Therefore, we regard this day as an intervention day, and as the intervention is via purchase, it is marked as 1. In another instance, on 29/09/2011, because the USD increased sharply internationally, traders expected that depreciation of the RMB exchange rate would occur. However, the Chinese state banks instead acted to sell the dollar at the market closing time, which mitigated the RMB's potential depreciation and so was

interpreted by market participants as an intervention. We therefore sign this date as -1, indicating sale intervention by the central bank.

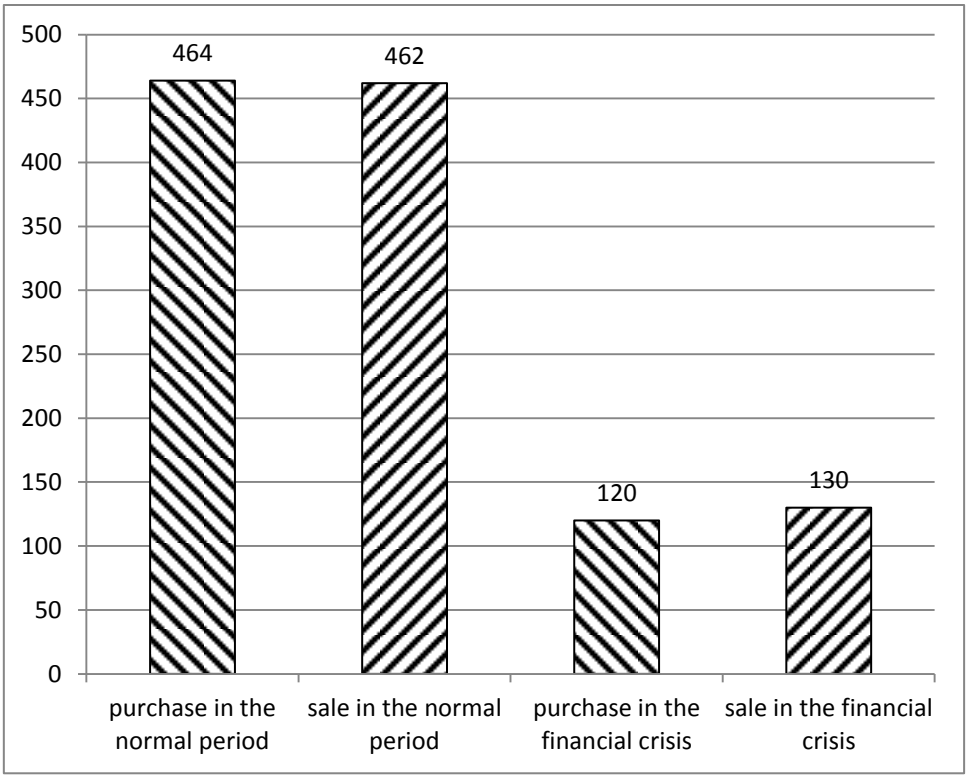
Table 1 presents the total number of intervention days and their composition in terms of purchase or sale intervention during the period under examination. It shows that during the whole sample period, the central bank purchased or sold foreign exchange on 1176 trading days. Analysis of the composition of the intervention days reveals that the PBOC does not use intervention only to address RMB appreciation, since if that were the case the number of purchase interventions would be considerably greater than the number of sale interventions, whereas the actual numbers are 584 for purchase versus 592 for sale interventions. Rather, the PBOC seems to be motivated mainly by a desire to stabilize the exchange rate movements and offset abnormal exchange rate volatility.

Figure 1 plots official intervention in the subsample periods. From the graph, one can observe that the number of purchase interventions is almost the same as that of sale interventions in the normal period (464 versus 462), but slightly less during the global financial crisis (120 versus 130). This difference indicates that during the crisis period the PBOC was more concerned about depreciation than appreciation.

Table 1. Official Chinese Interventions, 22 July 2005 - 22 July 2013

	Obs.	Mean	Std. dev.	Skewness	Excess Kurtosis
Total intervention	1176	0.842	0.832	0.301	1.510
Purchase intervention	584	0.560	0.898	0.981	1.962
Sale intervention	592	0.284	0.451	0.960	1.921

Figure 1. Purchase and Sale Interventions in the Sample Period



Note: The financial crisis period is defined as from 15 July 2008 to 23 June 2010; the rest of the sample time is the normal period.

4. Data and Variables

4.1 The Dataset

To empirically examine the determinants of intervention in China, we employ a daily time series dataset covering 8 years, from 22 July 2005 to 22 July 2013, based on information from newswire reports provided in Factiva and Reuters China. Excluding official holidays the whole sample period has a total of 2087 trading days. To further understand China's intervention, we divide the whole sample into two sub-periods: the global crisis period from15 July 2008 to 23 June 2010; and the normal period, which covers the rest of the sample time. From Figure 2, it can be seen that movements of the RMB exchange rate were flat from 15 July 2008 to 23 June 2010, a period during which, in response to the global

financial crisis, China re-pegged its currency. We also use the $\sup_{\gamma}(F(\gamma))$ test (Andrews, 1993) to formally check the structural break dates and hence the crisis period. The results are broadly consistent with our selected period. We reject the null hypothesis of no regime breaks at the 5% significance level.

Figure 2. Behaviour of the RMB/USD exchange rate

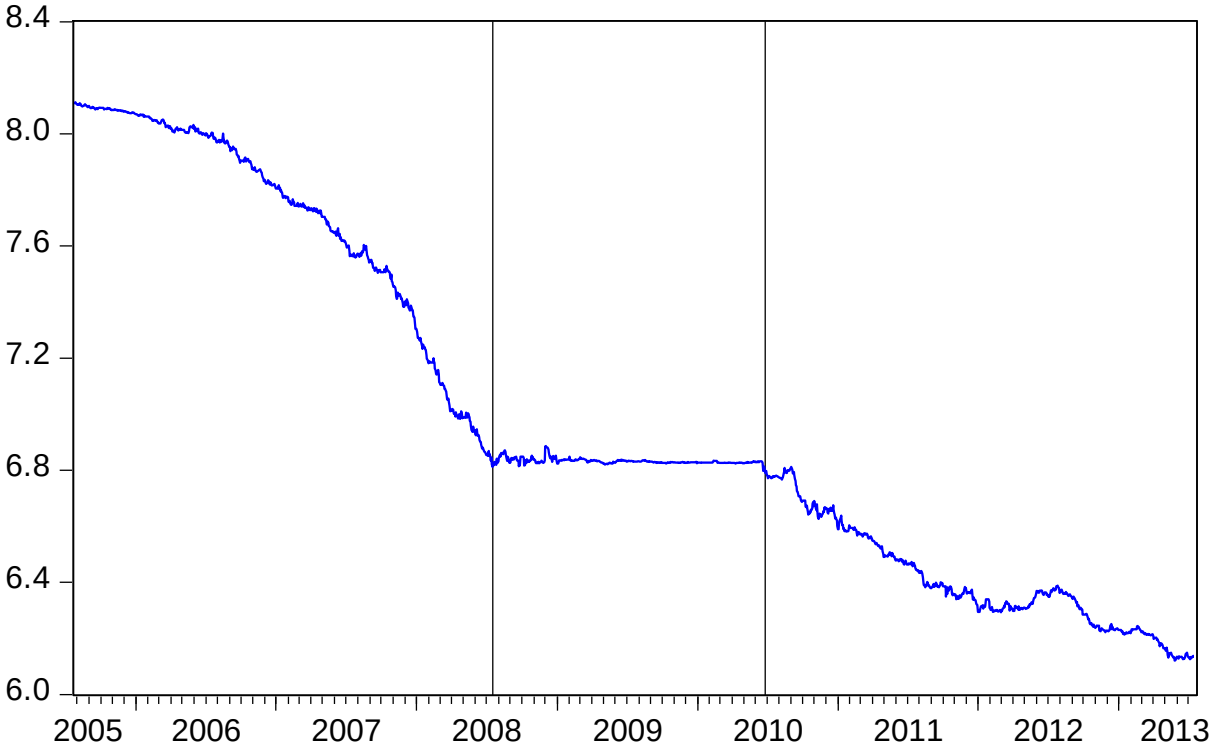
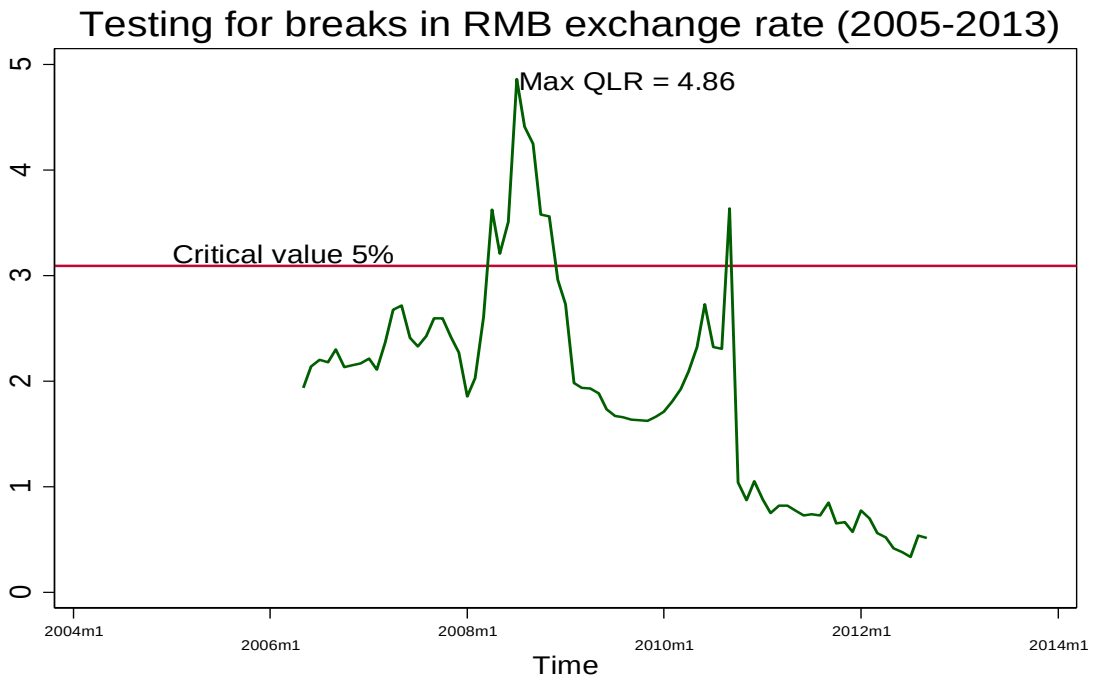


Figure 3. F tests for the regime breaks in the RMB exchange rate (2005-2013)



4.2 Model I (Basic Model)

Deviations from the trend level

Following Chen et al. (2012), we include two trend (target) exchange rates to analyse the determinants of China's intervention: the average of previous half year's RMB/dollar exchange rate as the medium-term trend (target), and the previous year's moving average rate as the long-term trend. Deviations from the trends are calculated as follows:

Medium-term deviation: $MDEV_t = s_{t-1} - \frac{1}{150}\sum_{i=1}^{150} s_{t-1-i}$ (1)

Long-term deviation: $LNEV_t = s_{t-1} - \frac{1}{260}\sum_{i=1}^{260} s_{t-1-i}$ (2)

It is reasonable to expect that a negative (positive) deviation, or appreciation (depreciation) of the RMB would induce a purchase (sale) intervention by the PBOC. So, in

the case of RMB appreciation relative to the US dollar, the PBOC would lean against the wind to engage in a purchase intervention by purchasing US dollars.

Conditional volatility

According to Kim (1998), Akinci et al. (2006), Hou and Li (2015), and Sharma and Vipul (2015), GARCH (1,1) models with Student-t distribution are helpful to estimate the conditional volatility of daily exchange rate changes. In this study, a GARCH (1, 1) model is deployed to estimate conditional variance of the RMB exchange rate in the whole sample period:

$$\Delta s_t = \beta_0 + \beta_1 \Delta s_{t-1} + \beta_2 \Delta s_{t-2} + \beta_3 Interest_t + \beta_4 GB_t + \beta_5 I_{p,s,t-1} + \varepsilon_t \quad (3)$$

$$h_t = \alpha_0 + \alpha_1 h_{t-1} + \alpha_2 \varepsilon_{t-1}^2 + \alpha_3 Interest_t + \alpha_4 GB_t + \alpha_5 I_{p,s,t-1} \quad (4)$$

where Δs_t is the log difference of the RMB/USD exchange rate. $Interest_t$ is the Shibor rate, or the Shanghai inter-bank offer rate, which is used because of possible effects of the interest rate on the exchange rate. GB_t is the Chinese government bond yield, used as a proxy for risk measurement. I_p and I_s represent purchase and sale interventions, respectively. Appendix A reports the results from estimating the GARCH (1, 1) model. Given that one major objective of the PBOC is to stabilize the foreign exchange market, we expect that conditional volatility has a positive relation with intervention.

Lag of intervention

Intervention is a sequential action. The central bank may intervene on different days and its effects may last into the next period. In addition, the lag of intervention could reflect the political cost (Ito and Yabu, 2007). We use a lagged intervention variable to study its dynamic effects on triggering subsequent intervention action.

4.3 Model II

Conditions of the national economy

The national economy variable has a mutual relation with the exchange rate. Every year the Chinese government publishes the target GDP growth rate. In the process of reaching the growth target, the exchange rate is often used as a policy tool to influence external trade. To this end, government intervention plays a pivotal role in bringing the exchange rate to the level desirable for trade promotion. Given the availability of data at daily frequency, conditions of the national economy are proxied by the national stock price index.

Dummy variables for exchange rate changes and size of volatility

In order to study the different influence of exchange rate volatility in episodes of yuan appreciation or depreciation, we introduce two dummy variables: one for yuan appreciation, which takes the value of 1 when the yuan is appreciating and zero otherwise; the other for yuan depreciation, which takes the value of -1 when the yuan is depreciating and zero otherwise. We also use a third dummy variable, which takes the value of one when the conditional volatility is greater than the average level of volatility for the sample period and zero otherwise, to test the impact of size of volatility on China's intervention decision. These dummy variables allow us to test whether high levels of volatility could lead to intervention.

4.4 Model III

Interest differential

Interest differential can be a proxy to indicate the possible degree of exchange rate overshooting (Kim and Sheen, 2002; Dimitriou and Simos, 2014). In this paper, the interest differential is calculated as the difference between the overnight Shibor rate and the US Federal Funds rate. If the interest rate differential increases (decreases), the RMB exchange rate will fluctuate upwards (downwards). The greater the exchange rate fluctuation, the higher is the possibility that the PBOC will step in to intervene.

Deviations from the central parity

In the sample period, China published the central parity rate on every business day from 22 July 2005. The parity indicates the benchmark for RMB rate movements and is used by the authorities to anchor the RMB exchange rate system. If the RMB exchange rate exceeds or is below the central parity by too great a margin, the PBOC will intervene to address the undesirable situation. As such, deviations of the RMB exchange rate from the central parity can be considered as an indicator of the possible advent of official intervention.

Liquidity index

Liquidity of foreign reserves could be a factor that leads to intervention. In order to maintain the desired level of international reserves, central banks use intervention to adjust the reserve stocks. We use the ratio of foreign reserves to imports as an indicator of China's international liquidity. Given the daily frequency needed for the empirical analysis in this research,

following Kim and Sheen (2002) we convert the monthly reserves and imports data to daily frequency through the spline function.

Foreign direct investment

Foreign direct investment (FDI) is a major channel through which international capital moves in and out of China. It is also an extremely important driver behind China's economic growth. Therefore, this variable has become a focus of policy attention in China, and its changes may trigger government intervention to influence international investments towards China. Therefore, we add the FDI variable to our models. To be consistent with other variables, we also convert the monthly FDI data to daily frequency.

4.5 Data Statistics

Table 2 below shows the summary statistics and stationarity tests for the variables. The results suggest that while variables such as deviations from previous 150-day and previous 260-day exchange rates, conditional volatility, deviations from the central parity, and FDI are stationary processes, other variables such as the liquidity index, stock price index, interest differential and the RMB/USD exchange rate are non-stationary. However, these series may be stationary if taking into account the regime breaks during the sample period (broken-trend stationarity).

Table 2. Data Summary Statistics

	Dev260	Dev150	Stock index	Interest rate differentials	Conditional Volatility	Central Parity	Reserves ratio	FDI	RMB/USD exchange rate
Observations	2087	2087	2087	2087	2087	2087	2087	2087	2087
Mean	-0.0112	-0.0031	55.8076	0.4303	-14.2758	-0.0037	20.087	9.8624	6.9879
Median	-0.0069	-0.0012	58.28	1.07	-13.9956	-0.0004	20.4718	5.7414	6.8287
Maximum	0.0739	0.0556	104.18	13.69	-11.3667	0.06957	37.58	110.3277	8.109
Minimum	-0.1588	-0.1664	26.07	-3.93	-17.0827	-0.0674	12.2317	-36.6187	6.1214
Standard deviation	0.0198	0.0105	14.1108	2.5421	1.2744	0.1961	4.4964	22.1494	0.6224
Skewness	-1.5311	-2.3939	-0.0355	-0.0712	-0.5907	-1.1594	0.5414	1.4572	0.5283
Kurtosis	9.6485	9.9252	3.2338	2.5415	2.5168	6.4435	3.7458	6.9504	1.941
Stationarity test	Stationary	Stationary	Mixed	Mixed	Stationary	Stationary	Mixed	Stationary	Mixed

5. Modelling China's Official Intervention

Rather than use an ad hoc method, we follow the approach of Almekinders and Eijffinger (1996) to derive formally the intervention reaction function. Specifically, the intervention reaction function is estimated by combining the exchange rate model with a loss function for the central bank. The exchange rate process is as follows:

$$s_t = s_{t-1} + \rho I_t + \omega Z_t + u_t \quad (5)$$

where I_t is intervention, Z_t is the past information set, and ω is a row vector of coefficients.

The central bank is assumed to have a loss function that should be minimized through intervention. The loss function to be estimated is:

$$\mathrm{Min}_{I_t} E[\mathrm{Loss}_t | \Omega_{t-1}] = E[(s_t - s_t^*)^2 | \Omega_{t-1}] \quad (6)$$

where Ω_{t-1} denotes the information available to the monetary authorities and market participants at the end of date $t-1$. The specification means that the losses are defined by squared deviation of the actual exchange rate from the target rate at time t.

Minimizing the loss function (6) by choosing I_t subject to the constraint (5) leads to the following intervention reaction function:

$$I_t^* = -\frac{1}{\rho}(s_{t-1} - s_t^* + \omega Z_t) \quad (7)$$

We then generate a binary choice dependent variable to represent the probability of two types of intervention, i.e. purchase and sale intervention. One fundamental advantage of probit regression is that the dependent variable can be a dummy variable. We use this modelling strategy to characterize the probability of official intervention occurring on a given day. In addition, this approach enables us to analyse a purchase or a sale intervention together.

We use the bivariate probit model as in Heckman (1978) to test the determinants of intervention:

$$I_{p,t}^{*} = \beta_1 x_{1t} + u_{1t} \tag{8}$$

$$I_{s,t}^{*} = \beta_2 x_{2t} + u_{2t} \tag{9}$$

where $I_{p,t}^{*}$ and $I_{s,t}^{*}$ are latent variables. The actual intervention can be written as follows:

$$\begin{cases} I_{l,t} = 2 \; or \; 1 \;\; if \; I_{l,t}^{*} > 0 \\ I_{l,t} = 0 \;\; if \;\; I_{l,t}^{*} \leq 0 \end{cases} ; \; l = p, s \tag{10}$$

where p and s are purchase and sale intervention, respectively, and

$$I_{l,t}^{*} = \beta_{l,t} x_t + \varepsilon_t, \quad \text{with}$$

$$\beta_{l,t} x_t = \alpha_0 + \alpha_{l,1}\mathrm{LND_t} + \alpha_{l,2}\mathrm{MED_t} + \alpha_{l,3}\mathrm{CV_t} + \alpha_{l,4}\mathrm{I}_{l,t-1}$$

$$+\alpha_{l,5}(\mathrm{CV_t})(Dapp_t)(Dsize_t) + \alpha_{l,6}(\mathrm{CV_t})(Ddep_t)(Dsize_t)$$

$$+\alpha_{l,7}\mathrm{SI_t} + \alpha_{l,8}\mathrm{ID_t} + \alpha_{l,9}\mathrm{CP_t} + \alpha_{l,10}\mathrm{RR_t} + \alpha_{l,11}\mathrm{FDI_t} \tag{11}$$

where $\mathrm{Int}_{\mathrm{P,t}}$ is a dummy variable that takes the value of 1 when the type of intervention is purchase and zero otherwise; $\mathrm{Int}_{\mathrm{S,t}}$ is a dummy variable that takes the value of -1 when it is sale intervention and zero otherwise. $\mathrm{LND_t}$ and $\mathrm{MED_t}$ are deviations of the current exchange rate from the target exchange rate in the long term (moving average of RMB exchange rates in the previous 260 days) and medium term (previous 150 days), respectively; $\mathrm{CV_t}$ indicates conditional volatility of the RMB exchange rate; $Dapp_t$ and $Ddep_t$ are dummy variables for yuan appreciation and depreciation, respectively; $Dsize_t$ is a dummy variable taking the value of 1 if the size of exchange rate volatility exceeds the average level, and zero otherwise; $\mathrm{I_{t-1}}$ is the lag of the dependent variable. $\mathrm{SI_t}$ is the MSCI China stock index, which we use as a proxy for conditions of the national economy; $\mathrm{ID_t}$ represents interest differential between

the Shibor overnight rate and the US Federal Funds rate; CP_t denotes deviations of the current market exchange rate from the central parity; RR_t is the ratio of official holdings of foreign reserves to China's imports; FDI_t represents amount of foreign direct investment.

The bivariate probit model is estimated with the maximum likelihood method and adjusted by heteroskedasticity consistent covariance matrix (Huber/White), which can help eliminate the effects of heteroskedasticity.

6. Empirical Results

6.1 Whole sample results

Table 3 reports the results of estimation for the whole sample using the bivariate probit model. The estimation is focused on the determination of China's purchase and sale interventions. We divide these determinants into three sets: Model I (basic model), Model II and Model III. The basic determinants model includes exchange rate deviations, conditional volatility and lag of intervention variables; Model II adds the volatility dummy variables and the national economic conditions index, while Model III is an integrated regression, including variables such as central parity deviations, inventory imperatives, and FDI.

Table 3. Bivariate Probit Estimation for Model I (Basic Model), Model II and Model III

	Model I		Model II		Model III	
	Purchase	Sale	Purchase	Sale	Purchase	Sale
Constant (α_0)	-0.466**	-0.128	-0.838***	-0.431***	2.919**	-2.126
	(0.213)	(0.214)	(0.133)	(0.135)	(1.348)	(1.341)
Long deviation (LND_t)	1.778**	-3.478***	1.321	-2.913***	1.506	-4.436***
	(0.845)	(0.805)	(0.874)	(0.844)	(0.965)	(0.932)
Medium deviation (MED_t)	-38.437*	71.082***	-30.059	50.519**	-32.000	88.348***
	(20.273)	(19.210)	(21.681)	(20.954)	(24.230)	(23.609)
Volatility (CV_t)	0.042	0.225***				
	(0.062)	(0.063)				
Lag ($I_{l,t-1}$)	0.102***	0.285***	0.113***	0.297***	0.106***	0.266***
	(0.030)	(0.059)	(0.031)	(0.061)	(0.031)	(0.061)
Volatility $(CV_t)(Dapp_t)(Dsize_t)$			0.172***	-0.220***	0.184***	-0.209***
			(0.034)	(0.032)	(0.037)	(0.034)
Volatility $(CV_t)(Ddep_t)(Dsize_t)$			-0.178***	0.071*	-0.166***	0.090**
			(0.035)	(0.038)	(0.038)	(0.042)
Economy (SI_t)			0.004*	-0.009***	0.004*	-0.010***
			(0.002)	(0.002)	(0.003)	(0.003)
Interest rate differentials (ID_t)					0.011	-0.006
					(0.015)	(0.015)
Central parity deviations (CP_t)					1.705	-5.903***
					(1.685)	(1.722)
Inventory imperatives (RR_t)					-1.698***	-0.021
					(0.629)	(0.621)
FDI flows (FDI_t)					-0.200	0.377***
					(0.123)	(0.125)
log-likelihood	-2198.550		-2148.141		-2132.047	
Observations	2086		2086		2086	

Notes: Figures in parentheses are standard errors. ***means the coefficient is significant at the 99% level; **means significant at 95%; *means significant at 90%.

Results from Model I

For the basic determinants model, our analysis of the results begins by explaining the influences of exchange rate deviations. We find evidence that the long-term deviations have a positive and significant relation with purchase intervention, and are significantly negative for sale intervention, while coefficients on the long-term deviations α_1 are positively and negatively significant for purchase and sale interventions, respectively. This outcome suggests that a current depreciation (appreciation) of the RMB exchange rate could induce a higher probability of purchase (sale) intervention by the PBOC, giving empirical evidence supportive of the leaning-with-the-wind hypothesis. In addition, the coefficient on the medium-term deviation α_2 is negatively marginally significant for purchase intervention at the 10% level and positively significant for sale intervention at the 1% level, implying that medium-term appreciation (depreciation) of the RMB leads to a higher probability of purchase (sale) intervention. Therefore, the evidence suggests that in medium-term intervention decisions the PBOC applies leaning-against-the-wind interventions.

The coefficient on conditional volatility α_3 is positively significant, indicating that conditional volatility has a significant and positive influence on sale intervention in the whole sample period. That is, higher volatility of the exchange rate is associated with a higher probability of sale intervention. Given that a major policy objective of the PBOC is to stabilize the RMB exchange rate, it is conceivable that a higher degree of exchange rate conditional volatility boosts the probability of the PBOC increasing the supply of foreign exchange to the market, hence there is increased possibility of sale intervention. However, similar to the results from Kim and Sheen (2002), an increase in conditional volatility has no significant effect on triggering purchase intervention, presumably because withdrawal of liquidity from the foreign exchange market would serve only to intensify volatility of the exchange rate. As such, the signs for the variable of conditional volatility suggest that the

PBOC does not worry too much about market turbulence when the yuan is perceived to be strong.

The lagged intervention shows a statistically significant positive impact for both purchase and sale interventions, since the coefficients on the lagged intervention α_4 are positive and significant for purchase and sale interventions at the 1% level. This indicates that if a purchase (sale) intervention happened on the previous day, the likelihood of another purchase (sale) intervention occurring in the following days is high.

Results from Model II

In contrast to the results from the basic determinants model, in purchase intervention estimations the marginally significant effects of exchange rate deviations disappear. The reason seems to be that the Chinese monetary authorities use purchase intervention to control extreme volatility. Given that one of the main objectives of the PBOC is to stabilize exchange rate movements, it may choose to control exchange rate volatility by using purchase intervention. The negatively significant coefficient on long-term deviations α_1 for sale interventions shows that appreciation (depreciation) of the RMB leads to China's purchase (sale) intervention, supporting the leaning-with-the-wind hypothesis. On the other hand, the PBOC also uses lean-against-the-wind intervention in the medium term, since the medium-term deviations are shown to have marginally significant impacts on sale intervention and no significant impact on purchase intervention. Furthermore, the coefficients on lagged intervention α_4 are positively and statistically significant for both purchase and sale interventions. This suggests that intervention is a sequential process and the probability of intervention is higher when intervention has taken place on the previous day.

On days when it is at a level higher than its average, conditional volatility has positively significant effects on purchase intervention when the RMB is appreciating, and for

sale intervention when the yuan is depreciating. The coefficients on volatility dummy variables α_5 and α_6 are significantly positive and negative for purchase intervention, while for sale intervention the signs of coefficients α_5 and α_6 are opposite to those for purchase intervention. This offers evidence that a further rise in volatility associated with an appreciation (depreciation) induces the purchase (sale) of US dollars, in line with the PBOC's policy objective of not allowing big swings of the RMB/dollar rate. Compared with the results for the volatility variable in the basic determinants model, we find further evidence that there is higher probability that China's monetary authorities will engage in purchase intervention on days when volatility is greater than the sample average and when the yuan appreciates, but not when volatility is of the normal magnitude.

As can be seen from Table 3, the result for the coefficient on national economic conditions α_7 shows that state of the national economy has a positive and significant effect on purchase intervention probability, and has a negative and significant effect on the probability of sale intervention over the whole sample period. When China's economy is performing well (badly), the RMB/USD exchange rate tends to appreciate (depreciate). To promote growth through exporting (importing), purchase (sale) intervention is used as a tool to combat exchange rate appreciation (depreciation).

Results from Model III

Comparing the results from Model III with the estimates from Model II, we find similar outcomes for variables of exchange rate deviations, the volatility associated with appreciation or depreciation, the intervention lag and the national economy.

In sale intervention estimations, the condition of the national economy has a significant influence. It is plausible that the national economy variable is associated with international reserves and FDI (Table 4). Polterovich and Popov (2003) and Lin (2011) show

that countries with growing foreign reserves exhibit higher rates of GDP growth. In addition, Alfaro et al. (2004) and Azman-Saini et al. (2010) obtain empirical evidence that FDI has a positive impact on growth. As such, the PBOC would take all these factors into account in purchase intervention decisions.

Table 4. The Correlation between FDI, International Reserves and National Economy

	FDI	International Reserves	National Economy
FDI	1		
International Reserves	0.002	1	
National Economy	0.177***	0.227***	1

Notes: ***indicates that the coefficient is significant at the 99% level; **means significant at the 95% level, and * means significant at the 90% level.

The non-significance of the coefficient on interest differential α_8 indicates that the interest spread between China and the US does not affect China's intervention decision. The probable reason is that with capital controls in place, international capital movements in and out of China are restricted, hence relative changes of interest rates would not greatly influence the RMB's exchange rate (Wang, 2007; Sun et al., 2009; Guan et al., 2012). As such, interest differential is not a significant driver for China's intervention decision.

Deviations from the central parity are significant only for sale intervention, with a negative sign. In other words, when the market RMB exchange rate becomes greater than the central parity rate (depreciation), the likelihood of sale intervention is lower, meaning that the Chinese authorities would not proactively redress currency undervaluation. In order to get further details about the effects of central parity deviations, particularly the size effect, we additionally specify two dummy variables: $Bsize_t$ and $Ssize_t$ [1]. As indicated in Table 5, the purchase intervention decision is influenced by deviations from the central parity when they are greater than the average deviation level, and sale intervention is associated with central parity deviations that are below the average level. This implies that the Chinese

authorities would step in to intervene only when there is large scale depreciation or appreciation, which sheds further light on the behaviour of Chinese exchange rate policy.

Table 5. Estimation of Effects of Central Parity Deviations

	Foreign Exchange Market Model	
	Purchase	Sale
Constant (α_0)	2.100	-2.727**
	(1.348)	(1.360)
Long deviation (LND_t)	1.984**	-4.314***
	(0.942)	(0.904)
Medium deviation (MED_t)	-49.734**	80.149***
	(23.759)	(22.335)
Lag ($I_{l,t-1}$)	0.101***	0.262***
	(0.031)	(0.061)
Volatility (CV_t)($Dapp_t$)($Dsize_t$)	0.192***	-0.203***
	(0.037)	(0.034)
Volatility (CV_t)($Ddep_t$)($Dsize_t$)	-0.158***	0.090**
	(0.038)	(0.042)
Economy (SI_t)	0.004*	-0.010***
	(0.003)	(0.003)
Interest rate differentials (ID_t)	0.002	-0.014
	(0.015)	(0.015)
Central parity deviations (CP_t)($Bsize_t$)	10.622***	
	(3.209)	
Central parity deviations (CP_t)($Ssize_t$)		-7.570***
		(1.900)
Inventory imperatives (RR_t)	-1.198*	0.329
	(0.634)	(0.630)
FDI flows (FDI_t)	-0.214*	0.373***
	(0.123)	(0.125)
log-likelihood	-2126.145	
Observations	2086	

Notes: Figures in parentheses are standard errors. ***means the coefficient is significant at the 99% level; **means significant at the 95% level, and * means significant at the 90% level.

The liquidity constraint has a negative and statistically significant effect only on purchase intervention. That is, the greater the size of international reserves, the lower is the probability of purchase intervention. An increase in the international reserves implies an increase in the country's macro-prudent position, hence relatively less need for the PBOC to take action to combat appreciation.

In contrast, FDI has a positively significant effect on sale intervention. The probable reason is that, while a reduction in FDI weakens China's balance of payments position, this would reduce the PBOC's impetus to sell dollars to push RMB appreciation. This would induce more foreign direct investment in China.

6.2 Results from the financial crisis period

Table 6 presents the results from the examination of China's intervention policy in the 2007-8 global financial crisis period with the bivariate probit model. The evidence indicates that during this sub-sample period, the main objective of the PBOC was to maintain confidence in the RMB. The RMB was re-pegged to the US dollar and China engaged extensively in sale interventions to combat RMB depreciation. On the surface this appears counterintuitive, since in a time of global crisis, a country may need devaluation to boost the economy. However, for China, it seems that the authorities regard confidence as more important, as the public would generally consider depreciation to be a sign of weak economic conditions. Furthermore, it is interesting to note that, for sale interventions, the coefficients on medium- and long-term exchange rate deviations are positively and negatively significant, respectively. This result suggests that if the market exchange rate deviates from its medium-term average, the PBOC will adopt a lean-against-the-wind policy, thus increasing the probability of sale intervention. However, when the RMB rate deviates from its long-term trend, there would be less impetus for the Chinese central bank to intervene, and hence the PBOC would lean with the wind.

The national economy variable has a negative and significant effect on probability of sale intervention. This suggests that in times of financial crisis, in response to slower economic activity, it would be more likely that the PBOC would reduce sale intervention. This is in line with China's pro-growth policy, since reduced sale intervention would offset

RMB appreciation and consequently may help promote external trade and growth. The liquidity constraint variable is negatively related with sale intervention, indicating that an increase in China's holdings of foreign reserves would reduce the PBOC's drive to sell more dollars, and hence would reduce appreciation of the RMB exchange rate.

Table 6. Results for the Financial Crisis Period

Foreign Exchange Market Model		
	Purchase	Sale
Constant (α_0)	-2.631	6.529
	(3.732)	(4.221)
Long deviation (LND_t)	1.414	-7.303*
	(3.878)	(3.960)
Medium deviation (MED_t)	-49.194	245.774**
	(123.052)	(124.492)
Lag ($I_{l,t-1}$)	0.066	0.086
	(0.691)	(0.157)
Volatility $(CV_t)(Dapp_t)(Dsize_t)$	0.099	-0.069
	(0.152)	(0.143)
Volatility $(CV_t)(Ddep_t)(Dsize_t)$	-0.125	0.072
	(0.148)	(0.138)
Economy (SI_t)	0.012	-0.036***
	(0.013)	(0.013)
Interest rate differentials (ID_t)	0.096	-0.338
	(0.229)	(0.256)
Central parity deviations (CP_t)	22.699**	-30.679***
	(10.309)	(10.328)
Inventory imperatives (RR_t)	0.605	-4.399**
	(1.578)	(1.787)
FDI flows (FDI_t)	0.020	0.505
	(0.290)	(0.339)
log-likelihood	-465.168	
Observations	507	

Notes: Figures in parentheses are Standard Errors. ***means the coefficient is significant at the 99% level; **means significant at the 95% level and * means significant at the 90% level.

7. Conclusions

This paper examines the forces that drive China's intervention in the foreign exchange market through purchase and sale operations. Empirical evidence unearthed by this research suggests that exchange rate deviations, conditional volatility, lagged intervention, national

economic conditions, interest differential, deviations from the central parity, position of international liquidity and foreign direct investment have significant influence on China's intervention decision. The PBOC conducts intervention in a leaning-against-the-wind fashion in the medium term, while leaning-with-the-wind intervention is deployed in the long term. The investigation findings show that China intervenes through the conduit of buying or selling foreign exchange to influence the exchange rate level as well as to constrain volatility so as to prevent big swings in the RMB exchange rate. It is interesting that deviation of the RMB from its central parity is a powerful driver for PBOC intervention, highlighting the pivotal role of this parity in China's management of the exchange rate. In addition, we find that, in response to the global financial crisis, the PBOC prioritized maintaining confidence in the RMB and keeping its exchange rate stable. This sheds important light on the behaviour of China's intervention in the face of great financial crisis.

Note

1. $\boldsymbol{Bsize_t}$is a dummy variable that takes the value of one if the size of central parity deviations exceeds the average level, and zero otherwise. $\boldsymbol{Ssize_t}$ is a dummy variable that takes the value of unity if the size of central parity deviations is less than the average level, and zero otherwise.

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Appendix

Table A. Maximum Likelihood Estimates of Garch (1,1)

Mean Equation $\Delta s_t = \beta_0 + \beta_1 \Delta s_{t-1} + \beta_2 \Delta s_{t-2} + \beta_3 Interest_t + \beta_4 GB_t + \beta_5 I_{p,s,t-1} + \varepsilon_t$		
	Coefficient	Std.Error
Constant (β_0)	0.0001**	4.767e-005
Δs_{t-1} (β_1)	-0.140***	0.024
Δs_{t-2} (β_2)	0.007	0.024
Interest rate (β_3)	-2.343e-005	1.955e-005
Global bond (β_4)	-7.839e-005*	3.019e-005
Purchase intervention (β_5)	-2.876e-005	4.861e-005
Sale intervention (β_5)	1.423e-006	5.804e-005
Variance Equation $\hbar_t = \alpha_0 + \alpha_1 \hbar_{t-1} + \alpha_2 \varepsilon_{t-1}^2 + \alpha_3 Interest_t + \alpha_4 GB_t + \alpha_5 I_{p,s,t-1}$		
Constant (α_0)	-0.358***	0.047
Variance (α_1)	0.951***	0.003
Error (α_2)	0.025***	0.001
Interest rate (α_3)	0.002	0.003
Global bond (α_4)	0.022**	0.005
Purchase intervention (α_5)	0.004	0.011
Sale Intervention (α_5)	0.007	0.012
Skewness		4.48
Kurtosis		39.041
$Q(20)$		5.575
$Q^2(20)$		0.295
Observation		2086

Notes: ***means the coefficient is significant at the 99% level; **means significant at the 95% level and * means significant at the 90% level.